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Effect on the Grain Size Distribution when Preparing Sand Using Poker Vibrators

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ABSTRACT

At Aalborg University and other research institutions, model tests are performed on small-scale foundations. These foundations are often installed in sand which has to be prepared in a reproductive way. At Aalborg University the preparation is done by using poker vibrators. This paper investigates if this preparation technique affect the soil in regards to grain size distribution, homogeneity and stratification. The paper concludes that the preparation technique does not lead to any change of the soil.

KEYWORDS: Soil preparation, Vibration technique, Grain size distribution, Small-scale testing, Sieve test analysis

INTRODUCTION

At Aalborg University, model tests on small scale foundations installed in water-saturated sand has been performed since 1993. Here the purpose has been to test offshore foundations both for monotonic and cyclic loading. Therefore, a densely packed sand needed to be prepared for each test, and Baskarp Sand No 15 was chosen. To ensure a dense sand the preparation procedure includes vibration of the sand, by poker vibrators, in a specific pattern. Before vibration is initiated, the sand is loosened, but not changed (the sand is reused). Until now, it has not been investigated whether the vibration has any effect on the prepared sand. As the first sandboxes has been scraped, it has not been possible to investigate the used sands in these boxes.

The oldest sand container, which is still in use, is a pressure tank (*The Pressure Tank*) developed in 2004. This setup has been used for testing small-scale offshore wind turbine foundations such as mono bucket foundations and mono piles and has been used by (Sørensen et al. 2009), (Sørensen 2012), (Foglia 2015), (Knudsen et al. 2013), (Foglia et al. 2013), (Nielsen et al. 2015), (Nielsen 2016), (Nielsen et al. 2017b) and (Nielsen et al. 2017a). The test set-up has been adjusted through the years which in 2012 involved a change of the control system. A description of this system is given in (Nielsen et al. 2016). As the sand inside the pressure tank has never been changed, several 100 tests has been conducted in the same sand.

In 2013 a new sand box (*The Sand Box*) filled with water saturated sand was made and is described in (Thomassen et al. 2017). Here the same types of foundations were tested for example by (Thomassen 2016) and (Vaitkunaite 2016). As this setup is much newer, the sand has been used for less than 100 tests.

In 2016 the geotechnical laboratory at Aalborg University changed location. Therefore, all of the laboratory test set-ups needed to be emptied and moved. During the emptying of the pressure tank and the sand box, representative soil samples were taken. The sand in both test setups is Baskarp Sand No. 15, but is from two different shipments: one delivered in 1993 and another delivered in 2013. The aim of this paper is to document if the vibration has any effect on the sand in terms of: 1) grain size distribution and 2) soil stratification. All sieve tests on the used soil has been performed in 2016 and 2017 and is compared to sieve tests performed on the unused Baskarp Sand delivered in 1993 and sieve tests on unused sand in 2016.

METHODS

Preparation method using poker vibrators

The complete preparation process for the pressure tank is described in (Nielsen et al. 2016). This is the same technique that is used for the sand box as well. Firstly, the sand is loosened by an upward gradient created by a higher placed water reservoir. Loosening is done to ensure the same basis before each preparation. Secondly, the preparation of the sand itself begin where a grid with a mesh size of 20×20 cm is predefined over the sand surface. The poker vibrator is then turned on and slowly forced into the sand in the first grid point. When the tip of the vibrator is 5 to 10 cm from the bottom of the sand layer the vibrator is slowly pulled upwards. This procedure is then repeated in all grid points. After the vibration process the soil properties are controlled by conducting mini CPT i five positions. If the homogeneity and the properties of the sand is satisfied, the preparation process are completed. If not, additional vibration is performed until the soil conditions are satisfactory.

Sample taking and sieve tests analysis

For testing, foundations has been installed in the center of the pressure tank and the sand box. The soil close to the center has therefore been affected by the conduction of the tests them self, whereas soil close to the outer boundary has hardly been affected by the tests. All areas have though almost equally been affected by the vibration during the preparation. In order to investigate if there is a difference between the soil in the center (C) and close to the boundary (B) samples has been taken at the center and at one location near the boundary, as illustrated left in Figure 1. To investigate if the vibration preparation leads to any stratification of the soil, samples are also taken in three different depth, both in the center (C) and close to the boundary (B). The right part of Figure 1 illustrate the virtual vertical cut (A-A) shown on the left. Here it is shown that the depth d is defined positive downwards with the soil surface as a reference point ($d = 0$).

In total this gives 6 representative large samples from each test set-up: 3 depths at the center and 3 depths close to the boundary. The reason for taking large samples were the possibility for self-regulation and validation of if the soil samples were representative.

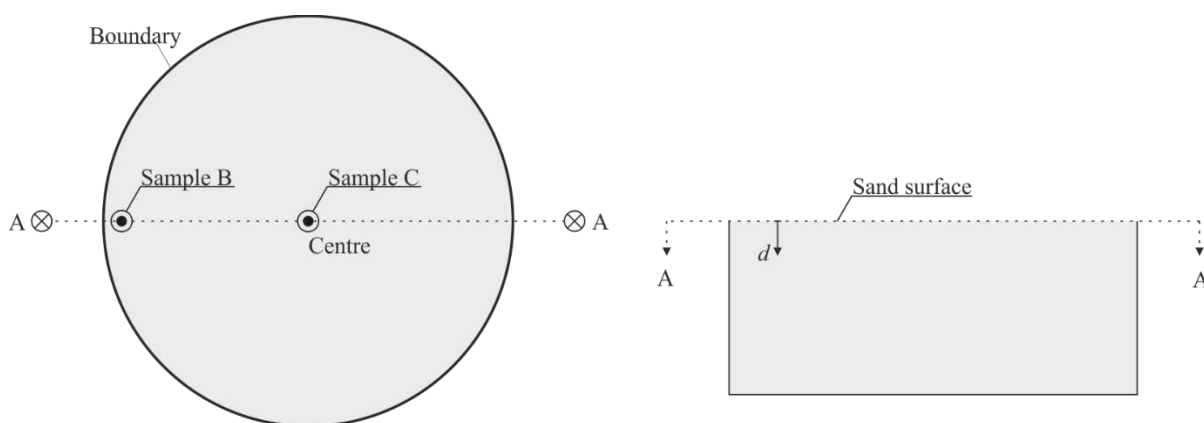


Figure 1: Illustration of the sampling method.

RESULTS

The results are divided into three. Firstly, sieve tests performed on the unused Baskarp Sand No. 15 made in 1993 and 2016 are compared in order to investigate if the grain size distributions are comparable. Secondly, the grain size distribution of the used sand from the pressure tank is compared to the original sieve tests performed in 1993 which is from the same delivery. Lastly, the grain size distribution of the used sand in the sand box is compared to the grain size distribution of the latest delivery of Baskarp Sand No. 15.

Grain distribution from delivered soil (unused)

The grain size distribution from both sands are shown in Figure 2. In 1993 five tests were performed (named A, B, C, D and E) and in 2016 four tests were performed (named A, B, C and D). Hereto, it should be mentioned that sieve mesh size and order are not identical in the tests from 1993 and 2016. However, Figure 2 indicates that the grain size distribution are not identical. Especially in the area around d_{50} the deviation has its maximum. For comparison, specifications on: d_{10} , d_{60} , U and d_{50} are given in Table 1. The deviation is most likely caused by the different sieve mesh sizes. Figure 2 only shows the results within the sand fraction, whereas the same results plotted in a graph showing grain fractions from clay to gravel is depicted in Figure 3. Both figures show that the deviation is small and will give the same characterization as fine sand. However, the variation is largest around d_{50} which might not have any influence, but could have been avoided by using proper sieve mesh sizes.

Table 1: Specifications on sand.

	1993	2012
d_{10}	0.087mm	0.090mm
d_{60}	0.155mm	0.135mm
U	1.78	1.50
d_{50}	0.145mm	0.125mm
φ_{tr}	40.1 I_D	39.3 I_D

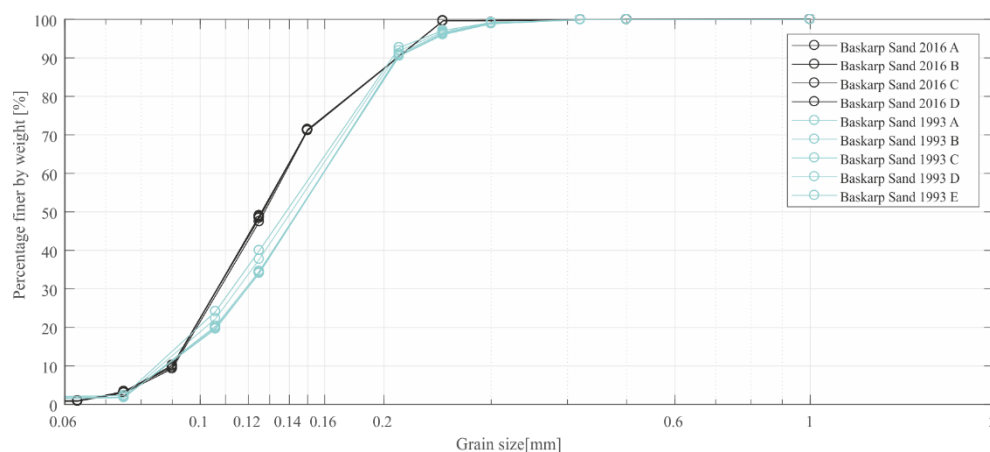


Figure 2: Grain size distribution of the sands delivered in 1993 and 2012. clay ($d < 0.002\text{mm}$), silt ($0.002\text{mm} < d < 0.06\text{mm}$), sand ($0.06\text{mm} < d < 2\text{mm}$) and gravel ($2\text{mm} < d < 60\text{mm}$)

The Pressure Tank (13 years of testing)

Figure 4 shows the grain size distribution of the tree sieve tests on the 1993 delivery and 12 sieve tests on samples taken from the pressure tank. Of the 12 tests from the pressure tank, 6 were taken from the center (C) of the pressure tank and 6 were taken close to the boundary (B) of the pressure tank. At each position two samples were taken in tree depths: 0.0 m (surface), 0.25 m and

0.5 m. A small deviation is observed, but in the same range as seen in the unused samples tested in 1993 and 2016. The small deviation is caused by the mesh sizes of the sieve tests. Therefore the samples from 2016 has been re-sieved using identical sieves as used in 1993. One sieve tests from each of the 6 samples are conducted, and the results are depicted in Figure 5. The figure show no or insignificant deviation between the used and unused samples. The deviation is therefore considered insignificant. Nonetheless, the largest deviation is found in the sand taken from the surface. Additionally, there is no sign of stratification as the grain size distributions from different depths are coinciding. Neither there is indications of out wash of fines as the lower tail of the curves are much alike.

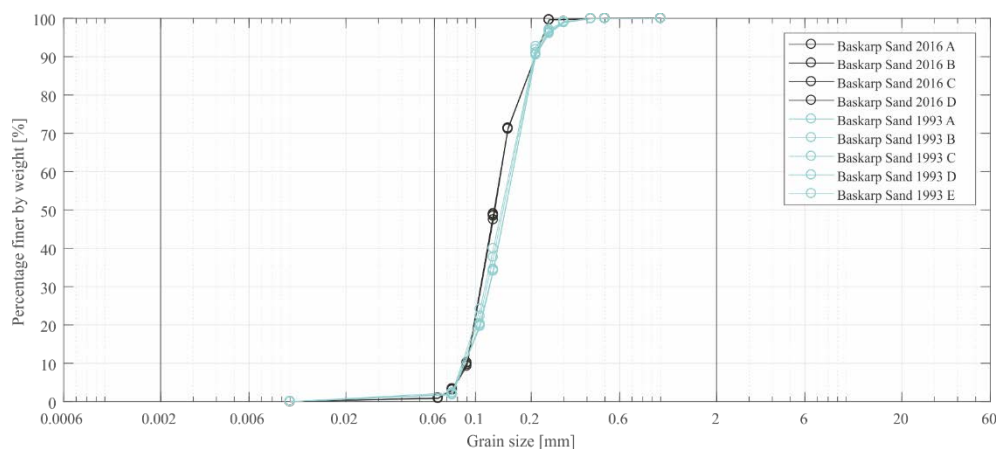


Figure 3: Grain distribution of the sands delivered in 1993 and 2012. Clay ($d < 0.002\text{mm}$), silt ($0.002\text{mm} < d < 0.06\text{mm}$), sand ($0.06\text{mm} < d < 2\text{mm}$) and gravel ($2\text{mm} < d < 60\text{mm}$)

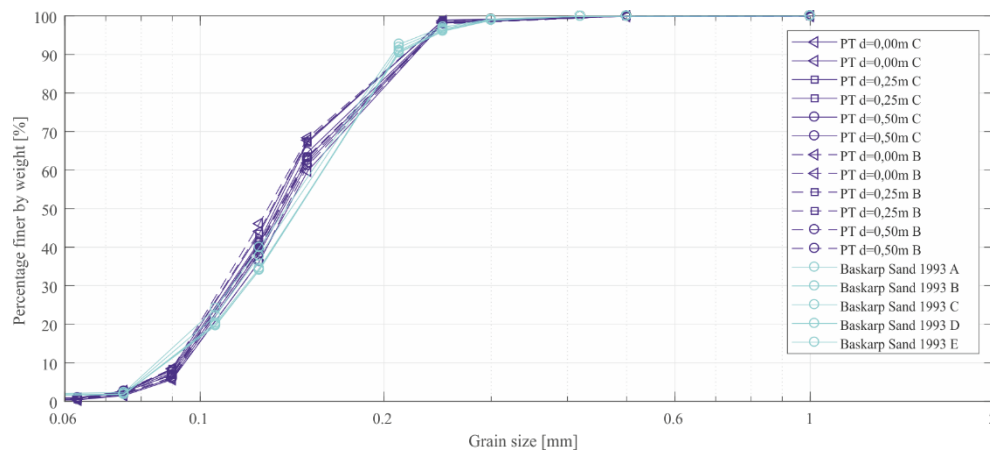


Figure 4: Grain distribution of the sand before and after use in the Pressure Tank.

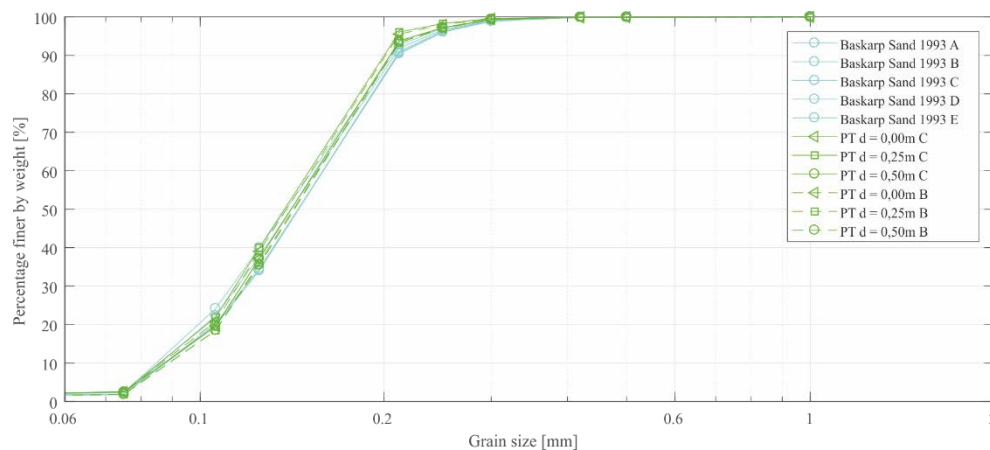


Figure 5: Grain distribution of the sand before and after use in the Pressure Tank. Sieve tests are performed with identical sieves.

The Sand Box (4 years of testing)

Figure 6 shows the grain size distribution of the tree tests on the 2013 delivery (sieved in 2016) and from 12 sieve tests on the used sand from the sand box. 6 taken from the center of the pressure tank (C) and 6 taken close to the boundary of the pressure tank (B). At each position two samples were taken in tree depths: 0.0 m (surface), 0.60 m and 0.80 m. Beside the samples taken at the surface, identical grain size distributions are found. Therefore, there is no sign of crushing, washing out of fines or stratification.

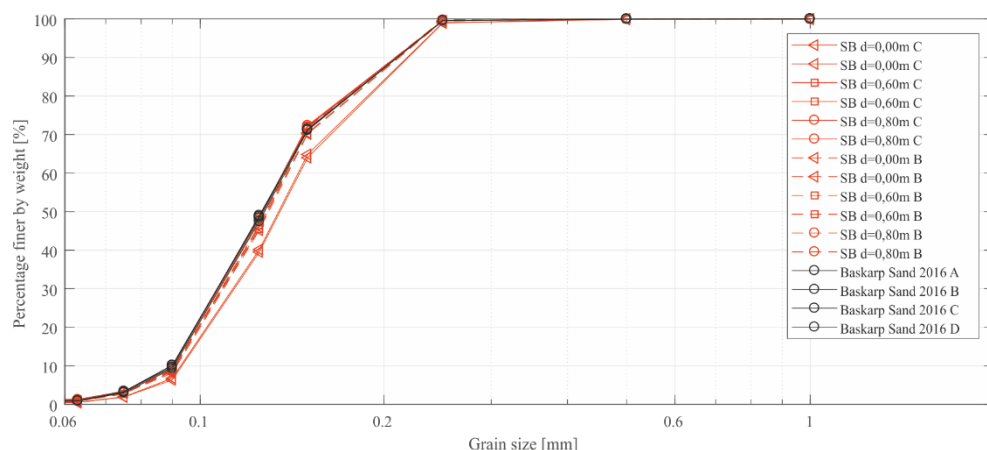


Figure 6: Grain distribution of the sand before and after use in the Sand Box.

DISCUSSION

Common for the sieve tests performed on material from the two test facilities is that the largest deviation is found in the used samples taken at the surface. Especially Figure 6 indicate that fines are might be affected by water movement just above the soil surface. But, the deviation is still small and is considered insignificant.

CONCLUSION

It is concluded that there is no sign of changed grain size distribution within the first 50-100 tests. Neither does it seem that there is any affect when the number of tests exceeds 100. Based on the above sieve test analysis, it is concluded, that preparation by poker vibrator do not lead to any change in grain distribution and homogeneity of sands and will neither lead to stratification of the sand.

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Editor's note.

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